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ABSTRACT

This unit, developed by the Third World Science Project, is designed to add a multicultural element to existing science syllabi (for students aged 11-16) in the United Kingdon. The project seeks to develop an appreciation of the: boundless fascination of the natural world; knowledge, skills, and expertise possessed by men/women everywhere; application of knowledge and skills to solve the practical problems of everyday life; impact of modern technology in the world; and the influence of the cultural background on the perception of knowledge, problems, and solutions. The unit consists of nine sections, beginning with an account of the local distillation of beer in Uganda using a homemade still. The measurement of specific gravity comes next, including class activities on making a simple hydrometer. The fractional distillation analysis of "enguli" (Ugandan fermented beverage) follows, with activities on using small experimental quantities. The next section, dealing with "alcohol power," is an account of how Brazil has made a national commitment to replace gasoline consumption with alcohol from sugar cane and cassave. The unit concludes with a discussion of how a Tanzanian student's interest in the alcoholic beverage (ulanzi) was developed into a useful science project. (JN)

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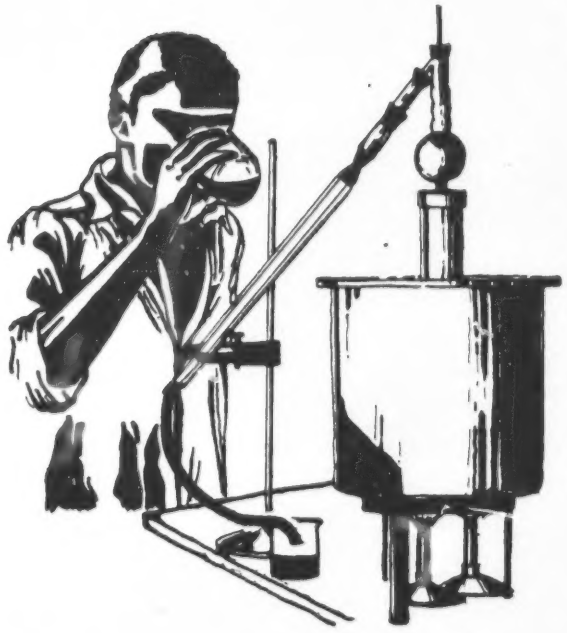

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DISTILLATION

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THIRD WORLD SCIENCE

Third World Science seeks to develop an appreciation of:

1 The boundless fascination of the natural world

2 The knowledge, skills and expertise possessed by men and women everywhere

3 The application of knowledge, skills and expertise to solve the practical problems of everyday life

4 The impact of modern technology in the third world

5 The influence of the cultural background on the perception of knowledge, problems and solutions

The following Units have been designed to fit into existing science syllabuses in the United Kingdom:

CARRYING LOADS ON HEADS: CHARCOAL: CLAY POTS:
DENTAL CARE: DISTILLATION: ENERGY CONVERTORS:
FERMENTATION: HOUSING: IRON SMELTING: METHANE DIGESTORS:
NATURAL DYES: PLANTS AND MEDICINES: SALT: SOAP.

The method of use is not closely prescribed. As resources teachers may use them in different ways though suggestions are offered. Feedback is invited from teachers concerning (a) the use made of the material (b) pupils reactions, if possible in their own words, and (c) suggestions for improvements, additions etc.

Please send feedback, ideas and requests to:

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DISTILLATION

Teacher's Notes

The unit begins with an account of the local distillation of beer in Uganda, using a homemade still. The measurement of specific gravity comes next including some suggested class activity on making a simple hydrometer.

It is assumed that the topics of distillation and fractional distillation have been encountered in an introductory chemistry course. The fractional distillation analysis of 'enguli' follows with some 'follow-up' practical work using small experimental quantities. Some questions requiring short answers are also included at the end of this section of the work.

The next section of the work on distillation deals with 'alcoholic power'. The dissertation includes an account of how Brazil has made a national commitment to replace petrol consumption with alcohol from sugar cane and cassava. Extracts from the Guardian and New Scientist are included to give an insight into the problems and weaknesses that have to be faced in pursuing this venture.

The unit concludes with an extract from an article by J.G.R. Briggs on 'A problem with alcohol'. This describes how one big pupil interest, which was a major disciplinary problem, was developed into a useful project.

DISTILLATION

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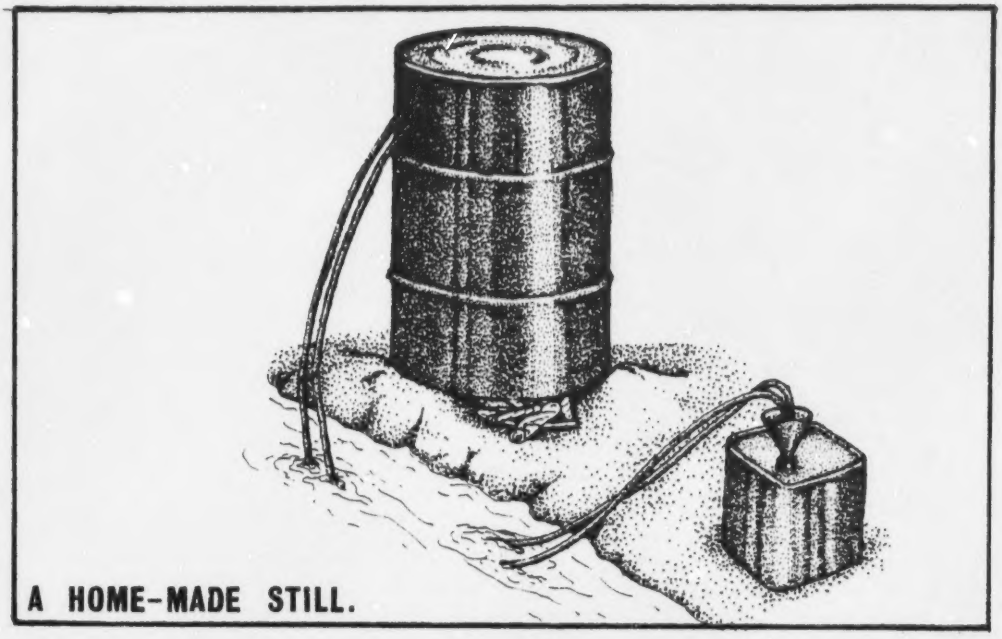
DISTILLATION

Almost every developing country has its own special beer produced by fermenting locally available material. In order to increase the alcohol content of these drinks the beer is distilled to give a crude spirit which quite often contains poisonous additional compounds.



A HOME-MADE STILL.

This technique shows some evidence of modern technology as the 'kettle' is a large oil drum, while the condenser is a pair of narrow copper tubes wound into a coil. The tubes are cooled by pouring cold water over them, or as shown in the picture by immersion in a nearby swamp. This distillate has to be raised to a height of half a metre or so above the level of the swamp, which is probably why narrow tubes are employed. A considerable pressure has to be maintained in the drums, and serious explosions are not uncommon.

In Uganda the home-made stills are used to produce a spirit called 'Enguli' which results from the distillation of the beer called 'Kkangala', which is brewed primarily from fermenting molasses or banana juice. The main reaction that takes place during fermentation may be summarized as follows:-

$$\underset{\text{cane sugar}}{C_{12}H_{22}O_{11}(aq)} + H_2O(l) \longrightarrow \underset{\text{Glucose}}{C_6H_{12}O_6(aq)} + \underset{\text{Fructose}}{C_6H_{12}O_6(aq)}$$

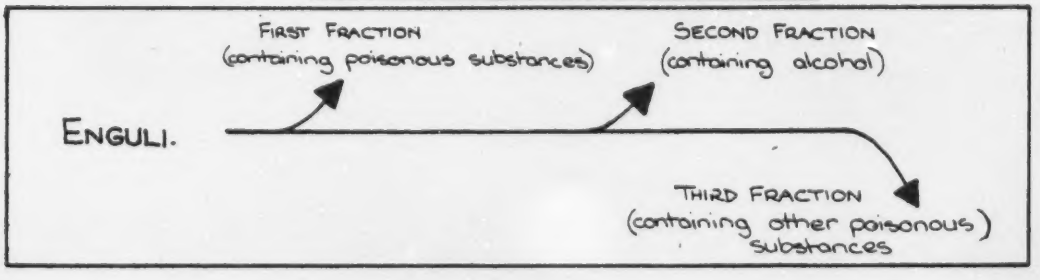
and

$$C_6H_{12}O_6(aq) \longrightarrow \underset{\text{Ethyl alcohol}}{2C_2H_5OH(aq)} + \underset{\text{Carbon dioxide}}{2CO_2(g)}$$

When the 'Kkangala' is distilled much of these harmful impurities pass into the 'enguli'. These impurities affect the smell and taste of the 'enguli'. Many minor constituents are poisonous: methyl alcohol is a particularly dangerous substance, able to cause mental disorders, blindness and death. 'Enguli' is thus not safe for human consumption and can be very dangerous if consumed in large quantities.

In the south of Ghana the favourite spirit is called 'Akpateshi' which is distilled from palm wine - the fermented sap of the palm tree which grow in the tropical rain forests of the south. The distillation process is similar to that of 'Enguli' in Uganda. Because of the absence of palm trees in the more arid north of Ghana, the northerners took to fermenting refined sugars and added other things to try and reproduce the 'Akpateshi' flavour, soap powder was one suggested additive! Unfortunately, the distillate produced contained dangerous organic impurities in addition to the alcohol. When the W.H.O. carried out a survey in the north of Ghana to assess the amount of blindness caused by the disease onchocirciasis (river blindness) which is endemic in the Volta Basin it was discovered that some of the cases of blindness could be attributed to the drinking of northern 'Akpateshi'! As a result of these findings and the general bad effect on the community, production of 'Akpateshi' in the north has now been banned.

THE DISTILLATION OF ENGULI.



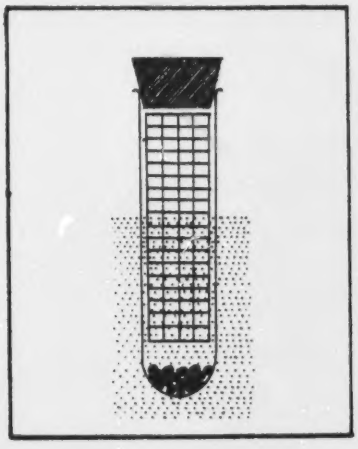
MEASURING THE SPECIFIC GRAVITY OF 'ENGULI'

In order to remove impurities from the 'enguli' and transformit into the palatable and safe drink 'Uganda Waragi', the 'enguli' is taken to the East African Distilleries plant at Port Bell near Kampala.

There the 'enguli' is examined and its ethyl alcohol content measured with a hydrometer. This is a simple instrument which is used to record quickly the specific gravity or density of a liquid in which it floats. A typical hydrometer (see diagram overleaf) contains a graduated scale on the stem and the reading at the surface of the liquid gives the specific gravity. The denser the liquid the less is the hydrometer immersed. In this case as alcohol has a lower density than water - the hydrometer will sink lower into the liquid (compare the diagrams overleaf).

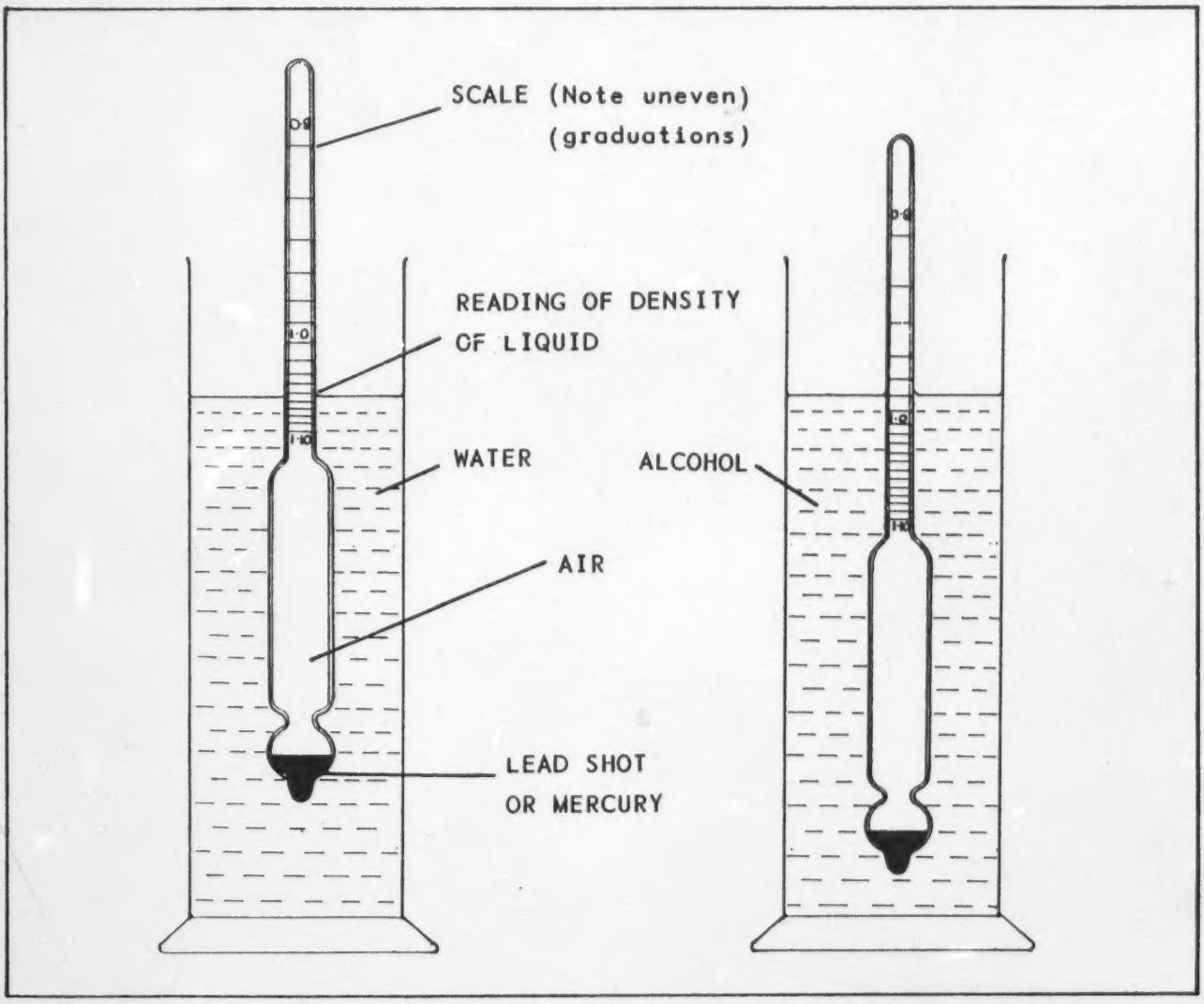
The 'enguli' makers are paid on the basis of the ethyl alcohol content.

Class Activity.



A model hydrometer.

Make a simple hydrometer from a test-tube. Paste a strip of graph paper inside the tube and load with lead shot so that when corked it floats in water up to the middle. Then float it in other liquids of known specific gravity to complete the calibration.



THE HYDROMETER

used for measuring the densities of different liquids.

FRACTIONAL DISTILLATION OF 'ENGULI'

When distillation is used to separate a mixture of liquids it is known as fractional distillation since during the process the original liquid is split into a number of fractions each containing one of the ingredients of the original mixture. The explanation is that when a mixture of two liquids is distilled in this manner the *more* volatile one (i.e. the one with the lower boiling point) tends to distil off first. As distillation proceeds the amount of the *less* volatile liquid in the distillate (the liquid coming over) gradually increases and so the boiling point rises.

In the distillation of 'enguli' the rectifying still separates the 'enguli' into three fractions. The 'enguli' is heated by steam, and when it boils, vapour passes through up the fractionating column. The first vapour to rise to the top of the column passes into the condenser, where it is cooled and condensed. The liquid so obtained is called the first fraction or the aldehyde fraction in this case. This consists of liquids of low boiling point; it is poisonous and is thrown away.

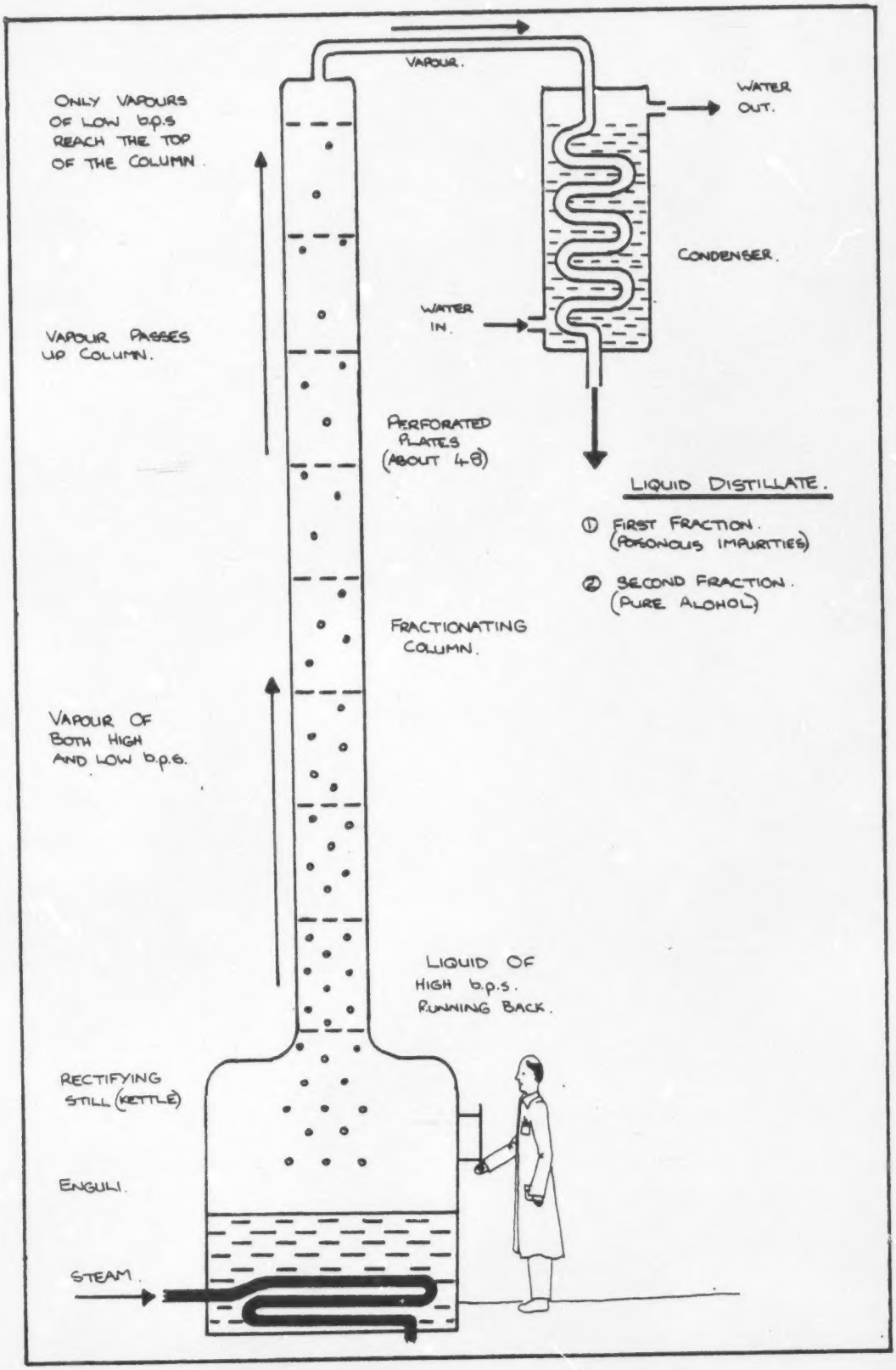
With further heating, the second fraction passes over. This contains the desired ethyl alcohol and is kept in storage tanks.

The third fraction containing higher boiling point liquids is not allowed to distil over and remains in the kettle or rectifying still. Like the first fraction it is thrown away because it is poisonous.

The still used may compare with a fractionating column used in the laboratory. The main difference is one of size. The industrial still which is about 9 metres tall, handles a much larger quantity and affects a better separation than is possible with a short column in the laboratory.

The industrial still employs a column with 48 perforated plates - though only a few are shown for clarity (see diagram). As the vaporised 'enguli' passes up through the plates some of the vapour condenses on the top side of each plate.

The tendency is always for the high boiling point constituents to condense and the low boiling point constituents to evaporate and remain in the vapour state. As the 'enguli' vapour bubbles up through the liquid condensed on the lowest plate, some of the low boiling point 'aldehyde' fraction already on the plate will evaporate and the vapour leaving this plate will be slightly more enriched with low boiling constituents than the vapour leaving the first plate. This process is continued up to the last and top plate. Here the vapour will consist almost entirely of the lowest boiling point constituents.



FRACTIONAL DISTILLATION OF ENGULI.

FRACTIONAL DISTILLATION ANALYSIS OF 'ENGULI'

Boiling Point	Substance	Properties
48°C	Propionaldehyde	Poisonous
56°C	Acetone	Poisonous
64°C	Methyl alcohol	Very poisonous; causes damage to the eyes which may result in blindness.
78°C	Ethyl alcohol	Harmless in small quantities causes intoxication and other harmful effects in large quantities.
100°C	Water	Harmless
119°C-130°C	Amyl alcohols	Very poisonous

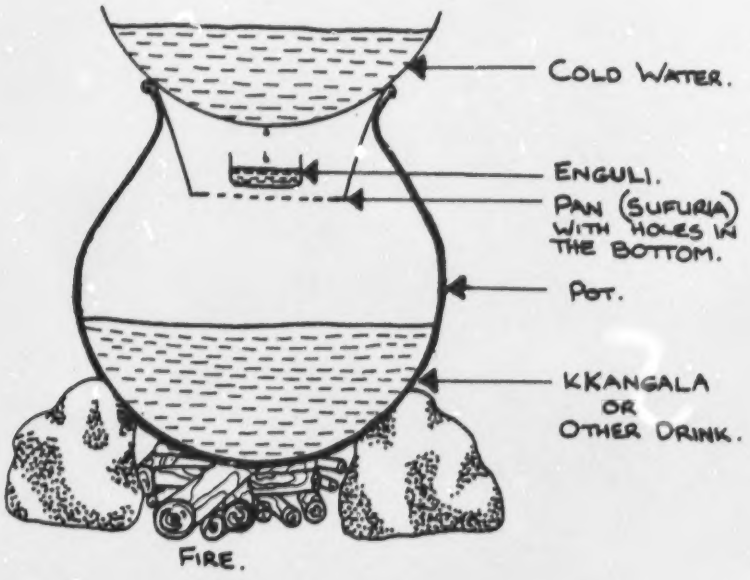
All the East African governments want to stop people from drinking harmful spirit drinks such as 'enguli'. In Kenya and Tanzania no one is allowed to make these drinks. Anyone doing so may be fined or sent to prison.

In Uganda, however, the government decided to licence 'enguli' makers and they are allowed to sell their 'enguli' only to the East Africa Distilleries Ltd., at Port Bell, but not to the public. The alcohol in the 'enguli' is then used to make a high quality national spirit drink known as 'Uganda Waragi'. All the poisonous substances in the 'enguli' are completely removed. 'Uganda Waragi' sells at a much higher price than 'enguli' and is a product of which the country is proud.

Finally the alcohol is mixed with distilled water and flavourings e.g. banana. The flavouring has a pleasant taste and smell. Six gallons of distilled water are mixed with four gallons of alcohol and a little flavouring to give 'Uganda Waragi'.

The main constituents of 'enguli' are ethyl alcohol (35-40%), and the remainder water. However there are also significant quantitiies of other compounds present, contained mainly in the high boiling point 'fusel oil' fraction and in low boiling point 'Aldehyde' fraction.

DISTILLATION OF SMALL QUANTITIES OF ENGULI.



1. What is the cold water for?
2. Why is it necessary to change the cold water several times?
3. What similarities are there between the large scale and small scale distillation of enguli?

Fractional Distillation of Small Quantities

For elementary classes, this experiment should be demonstrated by the teacher.

Apparatus

Round-bottomed flask, about 500 cm^3
Fractionating column and packing
Liebig condenser with rubber tubing to connect to water supply and sink
Bunsen burner, asbestos square, tripod, and gauze
Thermometer, - 10^o to + 110^oC, in cork or bung to fit fractionating column
Several beakers, 100 cm^3, to collect distillate
Three stands and clamps
Corks or bungs to assemble apparatus
Mixture of alcohol (industrial methylated spirits) and water, one part of alcohol to three parts of water
Pumice stone or pieces of broken porcelain

Procedure

Demonstrate fractional distillation by setting up the apparatus as shown in the diagram overleaf. The fractionating column may be packed with small pieces of glass rod or glass tubing.

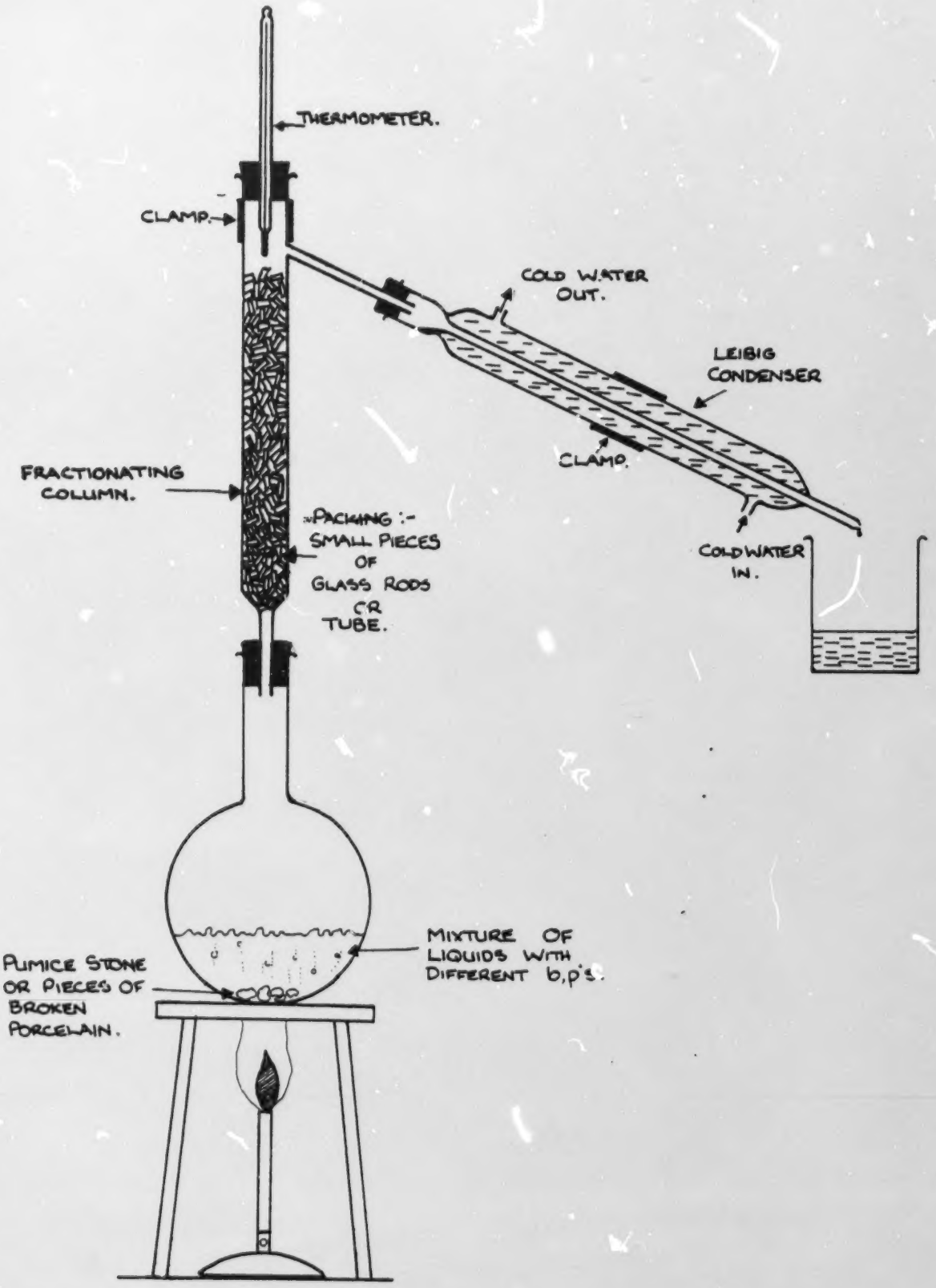
Important points to note are:-

1) the round-bottomed flask should not be more than a third full at the beginning of the distillation;
2) the thermometer bulb should be in line with the side-arm at the top of the fractionating column, to record the temperature of the vapour actually being collected; and
3) the cooling water should enter the condenser through the lower tube and leave by the upper one, so that the condenser jacket is always full.

Before starting the experiment, show that the mixture of water and alcohol will not burn.

Place a few pieces of broken porous porcelain or pumice stone in the round-bottomed flask to promote even boiling. Boil the liquid in the flask so that the distillate collects at the rate of two to three drops a second - take care to avoid boiling too rapidly or the column may 'flood' and a quantity of liquid will be forced over into the condenser. Watch the thermometer and collect different fractions in separate receivers. Note the boiling ranges of these distillate fractions and show that some, at least, of these fractions will burn. The proportions of water and alcohol present in mixtures of various boiling points are as follows:

FRACTIONAL DISTILLATION OF SMALL QUANTITIES.



Boiling point	% of ethanol
79°C	86%
80°C	83%
82°C	79%
84°C	76%
86°C	72%
90°C	62%
94°C	44%
98°C	19%

DISTILLATION

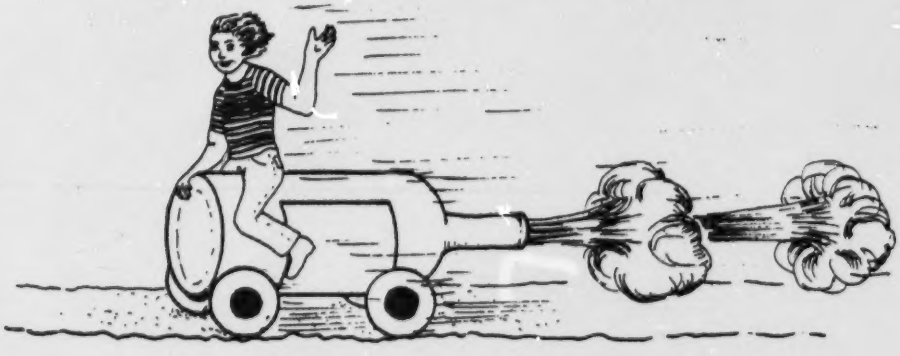
Questions requiring short answers

1. What is beer made from in Uganda and Ghana?
2. Where is sugar cane grown in Uganda?
3. Why is the 'Kkangala' distilled and what is the distillate called?
4. What is a still?
5. How much alcohol is there in 'enguli'?
6. What other substances are there in 'enguli'? (apart from water)
7. What is meant by a spirit drink?
8. Why is 'enguli' tested with a hydrometer?
9. Why is the 'enguli' fractionally distilled?
10. Which of the fractions contain poisonous substances?

Alcohol Power

Scientists now appreciate that the traditional practice of distilling alcohol from available resources could play a major role in providing the energy needs of village communities in tropical countries, especially as these are the areas which suffer most from the high world oil prices. Also the organisms used for the fermentation can be a source of single cell protein. Already, Brazil has made a national commitment to replace petrol consumption with alcohol. Tropical climates are ideally suited to the production of fermentable crops such as sugar cane, maize, bananas, palms etc, and the great advantage is that a lot of waste material from crops can be fermented and distilled to produce alcohol. This could be a useful addition to rural community energy requirements in the future.

Alcoholic Car Fuels



Brazil leads the world in the technology of making alcohol from sugar and cassava and using it in road vehicles, even exporting knowhow to the U.S.A. Its ambitious plans to reduce the country's dependence on petroleum spirit by making even more alcohol keep it ahead.

The Brazilian Government's Proalcool Project began in 1978 had saved over 1.6 million litres of petrol by alcohol substitution.

Through the distribution efforts of Brazil's national oil company Petrobras, virtually all the country's states and territories are now using the alcohol/ petrol blend. This has been made possible by the fact that neither cars nor pumps need to be modified and for this reason the blend has been maintained at a maximum of 20% alcohol. The government originally aimed for a 25% mixture, but severe corrosion of petrol pumps ruled this out. There are also over 200 pumps that serve pure alcohol to about 250,000 pure alcohol cars.

The reasons why Brazil should be pushing hard to find petroleum substitutes are not hard to find - it imports around 80% of its oil needs and has the

largest overseas debt in the developing world.

The choice of alcohol as a fuel substitute was an easy one to make. The incentive for the motorist is that the pump price of alcohol is only a third of that of petrol - even though alcohol has a 25% loss of efficiency due to calorific value. Alcohol has the advantage over petrol in that it is non-polluting when burnt in cars and can also be produced from regenerable feedstocks such as sugar cane. To cultivate sugar successfully, three things are necessary - sunshine, water and large tracts of agricultural land, and Brazil has plenty of all three.

To produce alcohol from sugar, the cane is crushed in large mangles, the resulting sugar is diluted, yeast culture is added and the liquid kept in large vats at the correct temperature until fermentation is complete.

The yeast culture acts on the glucose molecules to produce two molecules of ethyl alcohol and two molecules of carbon dioxide for each molecule of glucose. Formaldehydes, glucose and some superior alcohols are also produced but these comprise of no more than 0.2% by volume and are left behind in the final residue.

The fermented mass is then mechanically filtered to remove most of the solids and the resultant liquid submitted to ordinary fractional distillation where hydrated ethyl alcohol is taken off at 78°C.

The hydrated alcohol so produced contains 96% of ethanol at maximum and can be used directly as a fuel substitute in all-alcohol vehicles where a water content of up to 10% is perfectly acceptable. For blending with petrol, however, the alcohol has

Sugar cane.

to be completely anhydrous and this is achieved by azeotropic distillation with benzene or hexane. Benzene is more readily available and thus most commonly used. The benzene associates with the water and is left behind at 69°C, when it can be recycled for further use.

One of the great benefits of using sugar as a basis feedstock is that there is a net energy gain. The cane not only provides the basic fermentable sugars but also the bagasse fuel for running the distillation process.

Sugar cane takes 1½ years to grow to maturity and can be cut and cropped only twice in its lifetime. It is the biggest of all grasses economically important to man, growing to a height of 10 to 20 feet and sometimes more. Sugar cane is easy to grow. It needs a rich deep, well-drained soil, and a hot, moist climate with temperatures averaging about 20°C. The plant stores sugar mainly in the stem. New plants are raised from seed pieces cut from stem, new buds arising from the nodes. (See drawing)

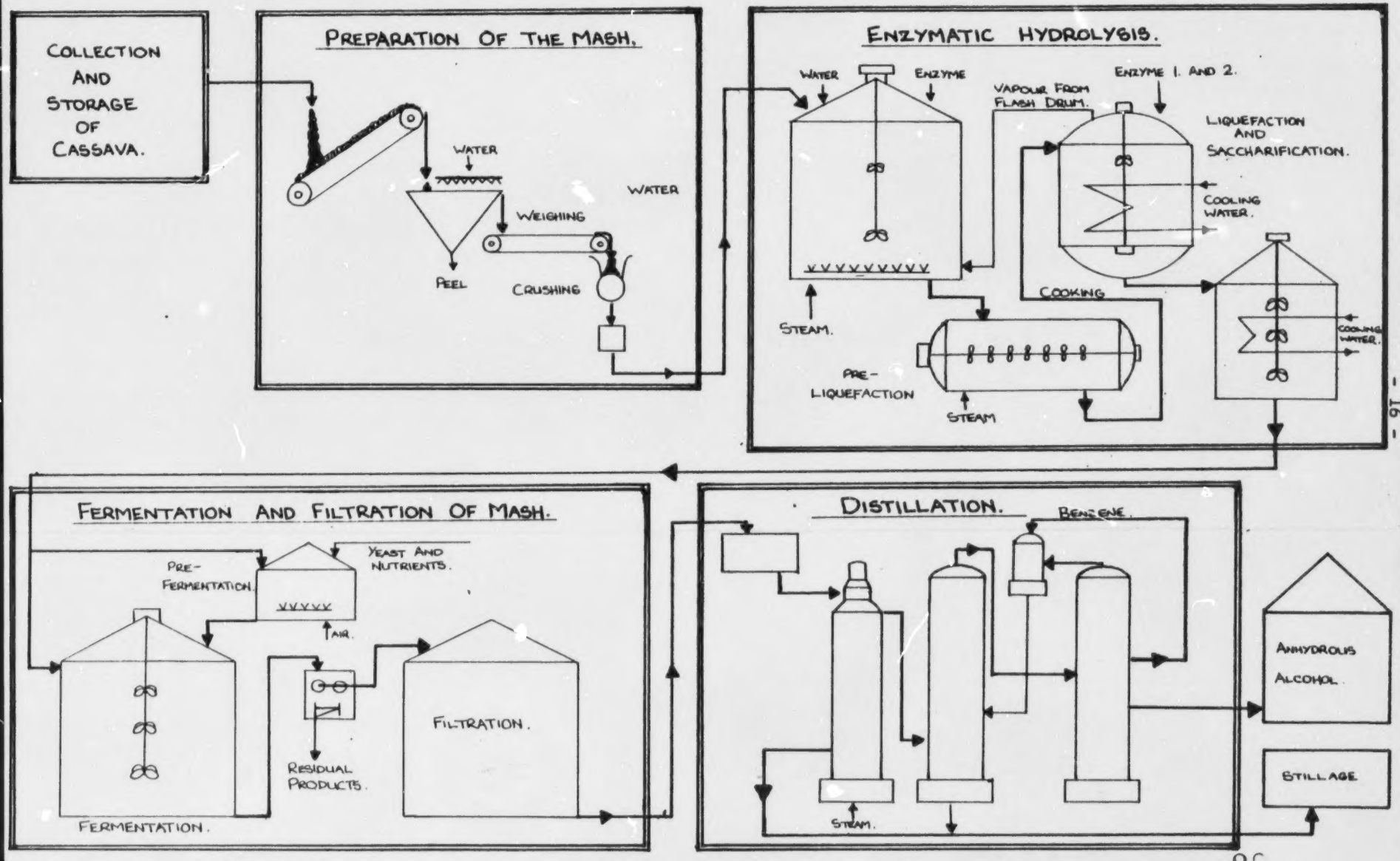
Brazil is utilising some of its best plant geneticists in an all-out effort to improve the amount of sugar produced per tonne of sugar-cane. But even now a mere 3% of the available agricultural land in Brazil would, if given over exclusively to sugar cane to produce alcohol, make the country self-sufficient in energy.

Sugar cane is just one of the available feedstocks, and in the future planners are likely to give more emphasis to a root crop which has provided the staple diet for the Brazilian poor from time immemorial - manioc or cassava. Producing alcohol from cassava adds an additional step to making it from sugar. First the starch in the root must be converted to sugar by enzyme treatment. Unlike sugar cane the cassava will grow almost anywhere, even in the poorest soil, provided the pH factor is to its liking.

Literally every part of the cassava root finds a use. The peel and residue from fermentation are used as high protein cattle feed, the carbon dioxide gas from the fermentation make dry ice and carbonated drinks. The root can also be dried, stored and treated in sugar cane refineries during the out of season period using excess sugar bagasse, resulting in a continuous alcohol production.

The disadvantage of cassava compared with sugar cane is that the starch content has to be converted to sugar before it can be fermented. To do this the root is peeled, crushed and mixed with water to form a crude mush with a fixed starch content. The mash is steamed to break down vegetable cell walls and enzymes added to convert the starch into glucose which can then be

SCHEMATIC FLOW DIAGRAM OF PETROBRAS CURVELO ALCOHOL PLANT.



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fermented and distilled in a conventional fashion.

As an amusing footnote, it has been decided in Brazil to blend the pure alcohol sold at the pumps with 3% petrol. This has nothing at all to do with improving the blend of the efficiency of the cars. It is simply that the national drink of the Brazilian is composed of virtually pure alcohol mixed with ice and fruit juices. The alcohol pumps were apparently fuelling not only the cars, but the driver as well.

THE GUARDIAN Thursday October 18 1979

Where alcohol ekes out petrol

ONE WAY of stretching the life of our oil reserves could be by blending petrol with methanol and higher cut alcohols. It is nothing new — for at least a decade Brazil has been using a mixture with up to 30 per cent alcohol for road transport. But Brazil is in a peculiar situation and what can be made to work there is not necessarily the answer for the British motorist.

Brazil has an appalling financial deficit, and the need to drastically reduce if not eliminate the spending of precious reserves on fuel which can be found in other ways is imperative. The country has land to spare and a climate that can produce four crops of sugar cane a year. They refine the crop, spread the remainder back on the ground as a fertiliser and thus have a constantly renewable supply of alcohol, though so far experts are not convinced that more energy is not going into the production process than comes out of the other end.

Now that fossil fuel has become so expensive, Brazil is going the whole hog and cars are being made in the country, notably by Fiat and Volkswagen, to run on a 100 per cent sugar cane-based alcohol fuel. I have driven the Fiat 127 derivative in this form and can detect no difference in its running against the petrol-fuelled model. The Brazilian Government is going in for a bit of gentle arm twisting to persuade motorists that it is all worthwhile. Petrol stations are closed when gasohol pumps are open at weekend and there is a heavy tax burden on petrol.

But will it happen here? Almost certainly not — there is simply not the land space available, nor the right climatic conditions to produce on the scale needed. But the "splitting" with petrol could come about. There are two principal types of alcohol fuels, ethanol and methanol. The first comes from growing plants, plant waste, whole grain and petroleum. Methanol can be made from wood, sewage, garbage, coal, natural gas, peat, shale, or tar, and beacuse of its more abundant sources appears to have greater scope as a substitute fuel.

Petrol/alcohol blends of up to 15 per cent can be used in existing cars without modification although some blends are particularly susceptible to contamination by water and some components must be replaced to avoid corrosion or erosion.

According to the SMMT, there is no clear evidence of the effect of alcohol blends on emissions though in some blends unpleasant, though not necessarily dangerous, odours can occur. The case for using petrol/alcohol blends rests more on balance of payments or regional development considerations rather than on strictly energy conservation aspects.

Alternative Fuels Take to the Bush

Brazil's fuel technologists think that scrub farming could help in their efforts to ease the country's high bill for oil imports. Current interest centres on the black quince bush which grows wild in a vast, semi-fertile region known as the Cerrado. This, the Brazilians hope, will provide them with a reliable source of diesel and some heavier oil products.

Techniques for extracting fuel from crops, especially from cane sugar, are well-established in Brazil. The country now has the world's largest industry for producing such liquids.

Recently, a near-bankrupt economy has been the result of the Brazilian government's major incentive for expanding gasohol production to keep imports as low as possible. An increasing quota of cars with engines designed to run on an ethyl alcohol-petrol mixture is produced in the country each year.

An increase in fuel production from vegetable sources-soya beans and cassava are the largest sources of alcohol and could lead to a reduction in export earnings from saleable commodities. But, by adapting otherwise useless plants such as black quince - no relation to the European fruit-bearing plant - to the technique, the Brazilians could enable regions such as the Cerrado, which has little irrigation, to make a useful contribution to the nation's income.

Researchers at the Ceará Federal University have shown that every part of the black quince will provide material for hydrocarbon fuel production. When completed, a pilot plant at Fortaleza in Ceará state, will process 20 tonnes of the bush each day. In the first stage of the process steam extraction produces 150 kg of light oils from each tonne of starting material. Later, a light solvent, alcohol for instance, can extract up to 50 kg of heavier oils. The final residue contains about 100 kg of a high protein animal food and 250 kg of wood which could fuel steam-rising for the first part of the process.

The pilot in Fortaleza will enable fuel technologists to assess other sources of diesel fuel such as peanuts and palms. Meanwhile, agronomists will solve the problems of how to tame a potential five million hectares of black quince.

A problem with alcohol.

Extracts from an article by J.G.R. Briggs - Head of Science Department at Sekolah Menengah Sains, Malayasia.

This article describes how one big pupil interest, which was in fact, a major disciplinary problem, was developed into a useful project.

In southern Tanzania quite a lot of bamboo grows. When the tops of young bamboo shoots (about 2 metres high) are cut off the sap runs out and can be collected - usually in a simple cup made from a piece of old bamboo. This bamboo juice, known as ulanzi, is very sweet when fresh and makes a refreshing drink. After some hours, self-fermentation occurs; the ethanol content increases and reaches a maximum after about two weeks. At the same time, the ulanzi becomes increasingly sour. During the season, ulanzi, is a popular drink, particularly as one can simply drink ulanzi of the correct age to obtain sugar/acohol balance of one's choice.

Unfortunately, ulanzi is readily accessible to schoolboys who are as attracted to alcoholic drinks as their British contemporaries. Boys were consuming large quantities of ulanzi and frequently returned to school drunk.

A group of senior boys, including some of the main 'offenders', were given the responsibility of collecting ulanzi so that its ethanol could be extracted. The ulanzi was kept at least 10 days to develop its maximum alcohol content and then distilled in a 50 dm^3 metal drum. The distillation was simple, using a splash head and a leibig condenser. The ethanol content of the distillate was monitored with a special alcohol hydrometer which happened to be available. The distillate was then double fractionally distilled and passed through activated carbon to remove the smell. A product was obtained which appeared indistinguishable from the 95% ethanol available commercially. This whole operation was carried out by the students with great enthusiasm and soon the chemistry laboratory had a regular supply of ethanol for experiments.

The next step was to put the ethanol to use and discover how many organic compounds could be converted from it. One of the aims of the project was to acquaint students with how chemicals are obtained. Fermentation, with the subsequent reaction of the ethanol product, is one of the few simple ways of showing this in school - it is also very cheap because the ethanol is free.

The excessive consumption of ulanzi was partly due to boredom on long weekends and the project went some way to providing an activity to fill that time. It also diverted energies from what was a purely socially destructive

practice and channelled them into something useful.

Home production of alcoholic drinks is a normal practice in many developing countries and the techniques are well known by the pupils. The starting materials range from maize and sugar cane to coconut palm. A class project on the local drink is one of the few ways of arousing pupils' interest in chemistry, enabling them to relate it directly to their own culture.

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T E C H N O L O G Y

Third World energy plant bugged by hiccups

ON THE SHORES of Lake Victoria, engineers are constructing an alcohol plant that should by rights be a showcase of how the Third World can exploit new and renewable energy. Sadly, the reverse is the case, but for different reasons than one would expect from a troubled project in the industrialised world.

The plant, based on well-established Swiss technology, is designed to turn molasses from sugar factories within the Nyanza region of Kenya into alcohol and several other useful products. Current plans are for the plant, at Kisumu, to produce 20 million litres of fuel alcohol (to be blended in the ratio of 15 per cent to 85 per cent with petrol); 3000 tonnes of citric acid for the soft drink industry, 1800 tonnes of bakers' yeast, and 2160 tonnes of vinegar. It will also produce sulphuric acid, fertiliser, gypsum and carbon dioxide. Sophisticated waste water treatment—accounting for 10 per cent of the capital cost of the plant—will also produce enough methane gas to supply 50 per cent of the plant's requirement for fuel.

On paper it sounds wonderful, but in practice it exposes all the weaknesses of developing industrialised technologies in a country whose people and markets have different priorities. First, the plant has been delayed by 16 months in the past two years, at a cost of about £325 000 per month. One delay was forced on the Kenya Chemical and Food Corporation when the main contractor went broke. The second was due to the government delaying cash grants because it was uncertain that the plant would ever be profitable. The plant will now cost £52·5 million (at present estimates), which is nearly double the original figure.

When it comes on stream, perhaps in the early months of next year, the plant will need feedstocks of molasses from several sugar factories within a radius of about 100 km. In theory, the plant will give a net energy gain of 5·2 billion kJ per year. However, Kenya's electricity authorities have not yet agreed to increase the electrical capacity of the local grid, so the plant will have to start up with diesel generators. Methane from the waste water treatment will not be available either in the initial stages, so diesel will have to provide power for process heat as well.

John Stansell, Nairobi

In the meantime, Kenya has two other alcohol plants under construction. One will produce another 20 million litres of alcohol per year by mid-1982, while the other, due to be completed in 1985, is three times bigger. Even 40 million litres of alcohol, blended in the ratio 15:85 with petrol, will exceed Kenya's current consumption of fuel. Although demand is rising at 7 per cent per annum, the 60 million litres of alcohol that the Riana plant will produce in 1985 will swamp the market. So far, the Kenyans have not worked out to whom they will sell the excess alcohol and at what price. And the multinational oil companies which supply Kenya's petroleum do not yet support the blend of alcohol and petrol.

Despite these problems the plant is generally accepted, even by its critics, as being necessary. Matthew Midika, a local MP, says that the additional employment—850 people directly and another 3500 indirectly—is essential in Kisumu, Kenya's equivalent of a grey area. Also, only 50 per cent of the present volume of molasses is exported, a figure that is likely to drop as the world price for sugar falls. The remainder was being dumped in the rivers, "killing my people", Midika says, so he welcomes any increase in its use.

Perhaps the main reason for continuing with the Kisumu plant, Midika says, is that it will show the world that the Kenyans are prepared to finish a project despite the difficulties. He says that a number of other high technology projects have been abandoned, with consequent damage to Kenya's credibility. Gillmore Bell, the managing director of Eximcorp, a Panamanian company that took over management of the plant in 1980, agrees up to a point. Ideally, he believes, the plant should be scrapped. The original feasibility study was poor (it only covered production of alcohol), the increases in cost have been devastating, the raw material will be imported from uneconomically large distances and the payback time will be at best nine years. Nonetheless, he concedes that in the environment of a developing country such as Kenya, circumstances are very different. He is open about the plant's weaknesses and the causes of them, but believes that the present targets will be met.

In the end, if plans do not go further awry, the losers will be those Nyanza locals who now use the waste molasses illegally to produce a local brand of gin known as Changaa. □

Distillation

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